

## Review

### Problem 1 Climate system

- What are the component subsystems of the climate system?
- What do the subsystems exchange with each other? What order of magnitude do the fluxes have (natural and anthropogenically perturbed)?
- Where is the boundary of the climate system? What is exchanged across this boundary?
- What do we mean by a climate in "equilibrium" (better term: steady state)?

### Problem 2 Radiation

- What are the sources of radiative fluxes in the climate system? What physical laws describe the flux sources?
- What are the magnitudes of the different fluxes?
- What is the greenhouse effect? Which atmospheric components are responsible for it?
- What is the radiative effect of clouds?
- What is the thermodynamic structure of the atmosphere in radiative equilibrium? What is the structure of the actual atmosphere, and why are they different?
- Derive TOA radiative balance, surface radiative balance, atmospheric radiative balance from radiative fluxes
- Is the atmospheric energy budget balanced? What would happen if not? What balances the radiative deficit?
- Meridional distribution of TOA energy imbalance

### Problem 3 Meridional energy transport

- Why is meridional energy transport required to maintain a steady-state climate?
- What are the mechanisms for meridional energy transport?
- What is the structure of the large-scale circulation of the atmosphere? Oceans?

#### Problem 4 Internal variability

- Why are climatological means calculated over long time periods?
- What is internal variability?
- What is a “mode” of internal variability? Examples?
- How does internal variability complicate the detection and attribution of climate change?

#### Problem 5 Forcing and feedbacks

- What is radiative forcing (RF)? What is the difference between radiative forcing and effective radiative forcing (ERF)? Examples of fast adjustments
- Examples of natural and anthropogenic radiative forcing; magnitude of RF due to CO<sub>2</sub> doubling; magnitude of present-day aerosol ERF, sources of uncertainty
- Why are TOA fluxes used to determine the sign of ERF?
- What is a (positive/negative) feedback? Name feedback mechanisms and their sign in the climate system
- What is the equilibrium climate sensitivity? How is it determined? Why is it uncertain?

#### Problem 6 Anthropogenic climate change

- What are the sources of uncertainty in projections of future climate?
- Anthropogenic carbon emissions: magnitude, relative to unperturbed fast carbon cycle?
- How do we know the observed climate change is anthropogenic?
- What is “committed” climate change?
- Patterns of temperature change
- Patterns of precipitation change